An Assessment of Options to Deal with Fuel-Related Air Quality Problems in Metro Manila, Philippines

United States-Asia Environmental Partnership

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List of Acronyms

ADB	Asian Development Bank
CARB	California Air Resources Board
CO	carbon monoxide
DENR	Philippines Department of Environment and Natural Resources
DOE	Philippines Department of Energy
EEP	Environmental Exchange Program
EMB	Environmental Management Bureau of DENR
EPA	United States Environmental Protection Agency
NOx	nitrogen oxide
PM10	particles less than 10 microns in diameter
RVP	Reid Vapor Pressure
SO2	sulfur dioxide
TSP	Total Suspended Particles
US-AEP	United States-Asia Environmental Partnership
VOCs	volatile organic compounds

EXECUTIVE SUMMARY

INTRODUCTION

As part of the United States-Asia Environmental Partnership (US-AEP) Environmental Exchange Program (EEP), two specialists in fuel-related matters from the California Air Resources Board (CARB) visited the Philippines to help identify candidate components of an air quality improvement program for Metro Manila. This assistance was requested by the Environmental Management Bureau (EMB) in the Philippines Department of Environment and Natural Resources (DENR), and the Asian Development Bank (ADB). The visit to Manila occurred the week of December 8, 1997.

Meetings were held with representatives of the EMB, ADB, the Philippines Department of Energy (DOE), the Bureau of Product Standards, the Philippines Institute of Petroleum, and with representatives of two oil companies, CALTEX and Shell. Information gained in these meetings, information from First Signs Corporation (a private company that operates air-monitoring stations), and additional research by the authors provided the information used to prepare this report.

RECOMMENDATIONS

Based on available emissions and air quality monitoring information, it is clear that Metro Manila experiences a very severe particulate air quality problem, one which is caused in large part by fuel combustion. The metro area suffers very high concentrations of fine particles called PM10 (particles less than 10 microns in diameter). Exposure to PM10 is linked to increases in respiratory diseases and increased mortality.

As requested by the EMB and ADB, the team is providing an analysis in three areas:

- design of a regulation to implement the required phase out of lead in gasoline,
- identification of other strategies to establish fuel specifications to reduce air pollution, and
- the design of a system to collect fees from pollution sources to support the activities of the EMB.

Recommendations for each of these areas are summarized below and discussed in greater detail in the Recommendations section.

A. **Design of a Regulation to Phase Out Lead in Gasoline:**

Implement the phase out of lead as scheduled (implement by 2000). This will greatly reduce ambient levels of lead, reduce PM10 by a small amount, and will enable the introduction of catalyst-equipped vehicles. A sample rule was drafted and provided to the EMB on December 18, 1997. Once lead additives are no longer used at the refinery level, the phase out should occur rapidly as leaded fuel is displaced with unleaded throughout the fuel delivery system. Based on CARB's experience on lead phase out in California, and knowing its impacts in the U.S. and other countries, the team does not believe that there will be any significant adverse impacts on existing in-use engines related to the switch to unleaded fuel.

B. **Identification of Other Strategies to Reduce Air Pollution from Fuel Combustion:**

1. *Fuel Specifications* Relative to the U.S., fuel quality in the Philippines is poor in terms of emissions-producing potential. Improvements in fuel quality would produce substantial emissions reductions and air quality improvements and can be accomplished over the next 1 to 5 years. Based on the team's analysis, the following changes to fuel specifications warrant consideration for implementation:

a. *Gasoline Specifications*

i. Lower the allowable Reid Vapor Pressure of Gasoline from its current limit of 12 pounds per square inch (psi) [expressed as 85 kPa] to 8.0 psi (implement by 2000). This will substantially reduce evaporative emissions of volatile organic compounds (VOCs) (and their toxic constituents), and lower exhaust emissions of VOCs and carbon monoxide (CO).

ii. Require all gasoline to contain minimum levels of detergent additives (implement by 2000) to prevent injector plugging and the increased emissions that occur as a result.

iii. Reduce the sulfur level in gasoline to at least 300 ppm from the current specification of 1,000 ppm (implement by 2002). This will achieve reductions in sulfur dioxide (SO_2) and will enable catalyst-equipped vehicles to maintain lower emission levels of pollutants.

iv. Cap the benzene level in gasoline at 2% for premium fuel and at 1% for regular fuel if sub-87 octane fuel designed for motorcycles and other two-stoke engines continues to be produced (implement by 2002). This would reduce emissions of benzene, a carcinogen that produces a substantial amount of the health risk associated with gasoline evaporation and exhaust, by about 50% from current levels.

v. Cap the overall aromatic hydrocarbon content of premium gasoline at 40% and at 30% for regular fuel (implement by 2002). This would also help lower benzene levels and reduce emissions of other aromatic compounds of concern.

b. *Vehicular Diesel Fuel Specifications*

i. Limit the sulfur content to 500 ppm by weight (implement by 2002). This will reduce emissions of sulfur-based particulates, and reduce gaseous emissions of oxides of sulfur which contribute to SO2 and PM10 problems.

ii. Limit the aromatic hydrocarbon content of diesel fuel to 25% and require a minimum cetane number of 50 (implement by 2002). These specifications will reduce PM emissions substantially, will provide a reduction in oxides of nitrogen, and will provide a higher quality and better burning fuel.

c. *Stationary Fuel Oil* -- Limit the sulfur content of fuel oil burned in stationary sources in Metro Manila to 0.5% sulfur by weight (implement by 2002). This will reduce SO2 emissions by over three-fourths from these sources, and would reduce particulate sulfate PM10 emissions by the same percentage as well.

2. *Changes in Type of Fuel* The strategies discussed above could provide substantial air quality benefits, but are unlikely to provide the degree of reduction needed to approach desirable air quality levels in Metro Manila. Therefore, in addition to identifying specific fuel specifications that could be established to reduce emissions from the current fleet, we also offer suggestions that could produce even greater benefits in the mid- to long-term time frame (5 to 15 years). These are:

a. *Natural Gas* -- Aggressively develop sources of domestic natural gas, and target large industrial and electricity production sources in Metro Manila for use of this fuel as soon as it becomes available. Even with only modest pollution controls in place, natural gas has much lower PM and SO2 emissions than fuel oil, and emissions of these pollutants could be dramatically reduced through such a strategy.

b. *Diesel Engine Replacement* -- At time of rebuild, replace diesel engines with gasoline engines in the light- and medium-duty vehicles used for passenger transport in Metro Manila. The "dieselization" of the people transport sector in Metro Manila, largely through the use of used engines retired from other Asian countries, has resulted in extremely high ambient concentrations of diesel particles. Gasoline vehicles inherently have much lower PM emissions and will create much less of an air quality problem.

c. *Natural Gas Buses* -- Concurrent with the delivery of domestic natural gas, introduce natural gas-fueled engines for the urban bus fleet and for other heavy-duty vehicle fleets with heavy use in the metro area.

d. *Light-Duty Diesels* -- Phase out the sale of new diesel vehicles in the light- and medium-duty categories unless such vehicles meet stringent PM standards so that their emissions are similar to well-controlled gasoline-powered vehicles.

C. Mechanisms to Fund Air Pollution Control Programs:

The following elements are offered for consideration in creating a simple system to collect air pollution fees. An example of how this system might work to create revenues of $5,000,000 (U.S.) is provided in the Recommendations section.

1. *Fees from Stationary Sources* Until an accurate source by source emissions inventory can be developed, a simpler system might include the following basic components:

   a. A permit fee that covers the direct cost of permitting the source and enforcing regulations via source inspections.

   b. A fuel use fee that produces the revenues from the industrial category needed to fund that category's "fair share" of the overall cost of conducting the air quality program. For example, if the industrial sector contributed one-third of the overall emissions, collectively the fuel-based fees would provide one-third of the revenues needed. The level of this fee could be based on the quantity of fuel used and the sulfur content of the fuel. A mechanism to lower the fee for sources that have emission control systems (for example a sulfur recovery unit) should be considered.

2. *Vehicle Fees* Establish a mechanism so that vehicular sources provide revenues in proportion to their contribution to the problem. Mechanisms might include the following:

a. A very small per-liter charge on vehicular fuel at points of production could be established. Again, this fee should be adjusted to reflect the relative emissions associated with the fuel. For example, combustion of a liter of diesel fuel produces far more of the pollutants that contribute to PM10 and SO2 problems than a liter of gasoline. The fee on diesel would be higher to reflect this difference.

b. An alternative approach would be to establish per-vehicle fees to be paid at the time of registration. These fees could be adjusted to reflect the emission characteristics of the vehicles.

c. In addition to the above, charges to vehicle manufacturers could be used to cover the resources devoted to certifying new vehicles and to enforcing the standards for these vehicles.

D. Other Observations and Items for Consideration:

In addition to evaluations of the phase out of lead in gasoline, identification of other strategies to improve fuels, and the design of a system to collect fees, several additional observations resulted from the team's assessment. These are presented below:

1. *Air Quality Monitoring* Expand the monitoring network to include a number of fixed sites that collect routine data on CO, SO2, ozone, and PM10. While sufficient information is available for Metro Manila to establish that there is a very serious PM10 problem, monitoring for other pollutants is incomplete. Although the limited monitoring available has not defined a clear problem, the heavy concentration of sources of CO, SO2, and toxic organic gases suggest that high levels of these pollutants are very possible.

   In addition, establish a program to measure high concentrations of CO, SO2, PM10, and toxic organic gases in areas affected by heavy traffic congestion. This could be accomplished by using a "rover" station that could be moved from site to site to collect short-term (several days to several weeks) monitoring data demonstrating the magnitude of exposures at suspected high sites.

   Finally, analyzing the content of the filters could determine much information about the nature of the PM10 problem. The contributions of secondary particles such as nitrates and sulfates could be determined, and the contribution of direct combustion particulates versus soil-based fugitive dust could be better estimated.

2. *Two-Stroke Motorcycles* Vehicle registration and fuel use information suggest that small, two-stroke motorcycles account for 10% of the vehicles and consume approximately 1% of the gasoline used in Metro Manila. (This amount could be considerably higher if a substantial fraction of the motorcycles utilize premium fuel.) Although a relatively small fraction of the vehicle fleet in the Metro area, these two-stroke-powered vehicles contribute a disproportionately large percentage of the toxic organic compounds and PM10 emissions in the area. This is due to the fact that these engines have extremely inefficient combustion characteristics. Several possibilities for alleviating this problem are as follows:

    a. Apply more stringent fuel specifications for benzene and aromatics if low octane fuel sold as regular gasoline continues to be allowed, and that fuelis offered principally for use in small engines. This gasoline can be manufactured with much lower aromatic and benzene levels without producing an octane problem.

    b. In addition to fuel controls, a program for removing motorcycles with excessive smoke should also be considered. Visible emissions are a clear sign of very high PM emissions and oil use. Forcing the repair or restricting the operation of these vehicles would produce a valuable contribution to reducing PM10 emissions.

    c. A policy of requiring all new motorcycles registered in Metro Manila to have four-stroke engines should be considered. On a per-kilometer-traveled basis, four-stroke engines have about one-sixth of the organic gas and one-eighth of the PM10 emissions as their two-stroke counterparts.

3. *Establish an aggressive program to prevent smoking vehicles* Many diesel vehicles in operation in Metro Manila emit excessive smoke. These visible emissions result in a many fold increase in an individual vehicle's particulate emissions. (Exhaust that has 50% opacity contains more than 10 times the particle mass than exhaust which is barely visible.)

   Smoke, and the resulting excess emissions, can be greatly reduced through engine adjustments and other routine maintenance. In many observed cases, the smoke was so severe that a visual inspection would be adequate to identify problem vehicles. A significant part of the diesel particle problem comes from these smoking vehicles, and this part of the problem can be corrected in the near term through an aggressive effort to remove these vehicles from operation until proper maintenance is performed.

PROGRAM DESCRIPTION

Assistance in identifying candidate components of an air quality improvement program for Metro Manila was requested by the Environmental Management Bureau (EMB) in the Philippines Department of Environment and Natural Resources (DENR), and the Asian Development Bank (ADB). The visit to Manila occurred the week of December 8, 1997. Advice was sought in three areas: design of a regulation to phase out lead in gasoline, identification of other fuel specifications that could be used to reduce air pollution, and the design of a system to collect fees from pollution sources to support the activities of the EMB.

Monitoring data provided by EMB and First Signs Corporation for 1997 shows that PM10 levels are many times more than is allowed in the U.S. or recommended by the World Health Organization. High levels occur at all sites and on most of the days monitored. Average readings for all stations in 1997 were far above the annual average U.S. standard of 50 ug/m3, and several times greater than the more protective California standard of 30 ug/m3. It appears that much of the PM10 is in the very small fine fraction (2.5 microns and smaller), and poses additional concern because it includes high levels of diesel particulates, which are a suspected human carcinogen.

Air quality for other pollutants is not routinely monitored, but past efforts indicate that these pollutants cause problems of lesser magnitudes than the PM10 problem. Lead levels were high when monitored in the early 1990s, but should have declined by more than half due to the introduction of “low lead” gasoline. Emissions information suggests that high levels of SO2 may be occurring. The extreme level of traffic congestion likely produces elevated levels of carbon monoxide (CO) and toxic volatile organic compounds (VOCs), such as benzene, at least in the immediate vicinity of busy traffic corridors.

Emissions inventories indicate that, with the exception of SO2, vehicle activity is the major source of problem pollutants. As part of this effort, a PM10/SO2 emission inventory was prepared using information on the quantities of fuel used, and this estimate was compared with previous inventories. This inventory was then used to assess the beneficial impacts that changes in fuel composition could have on emissions, but did not create a significantly different picture of the likely sources of Metro Manila’s air quality problems than that suggested by previous inventories.

In terms of directly emitted PM10, the overwhelming sources of vehicular emissions are diesel vehicles, which dominate the goods and people transport sectors in the urban area. Exposures to diesel particulates and other diesel exhaust constituents is very high throughout the metro area. In addition to adding significantly to PM10 levels, diesel emissions pose a substantial toxic pollution threat and likely are causing serious health problems to many of Manila’s residents.

DESCRIPTION OF ACTIVITIES

A. Air Quality Data

Available air quality monitoring information for Metro Manila was reviewed as part of the analysis. Recent data (for 1997) provided by EMB and First Signs Corporation was reviewed, as was the information contained in the 1992 report prepared for the ADB. From this information it is clear that Metro Manila experiences a severe small particle (PM10) air quality problem. Very high concentrations of Total Suspended Particles (TSP) occur at all EMB monitoring sites. Monitoring done by First Signs Corporation also confirms that the PM10 fraction of TSP readings are quite high. PM10 exposures cause increases in respiratory diseases and are linked to increased mortality.

Recent monitoring data (13 stations with measurements between July and October 1997) provided by First Signs Corporation show that PM10 levels are at least several times that allowed in the U.S. High levels occur at all 13 sites, and on most days.

The average of all TSP readings at all EMB-run stations for the first 9 months of 1997 was about 240 micrograms per cubic meter (ug/m3). The 24-hour readings for TSP are also very high. In 1997 (through September) the peak 24-hour value varied from a low of 182 ug/m3 at the Ateneo site to a high of 856 ug/m3 at the EDSA-DPWH site.

PM10 data was reported by First Signs Corporation for a total of 18 days, on a once-every-six-days schedule beginning on July 7, 1997. An annual average reading is not yet available from this data, but 24-hour readings are very high, and it is clear that many stations will exceed the annual average U.S. standard of 50 ug/m3 by several hundred percent.

The First Signs data also show that all 13 stations exceeded the U.S. 24-hour standard of 150 ug/m3 many times. This level was exceeded at four sites on every day monitored. Of the approximately 200 readings reported by First Signs for all 13 sites, about 75% exceeded the U.S. EPA 24-hour PM10 standard (150 ug/m3), and all but two exceeded the more protective California standard of 50 ug/m3. The peak reading recorded was 535 ug/m3, and 14 readings were more than twice the U.S. EPA 24-hour standard.

Pollutants other than PM10 and TSP are not routinely monitored, but the data available suggest that while these pollutants may pose problems, they pose health threats of a lesser magnitude than those produced by PM10. Lead levels were high when monitored in the early 1990s, but should have declined due to the introduction of "low lead" gasoline. Emissions information suggests that high levels of sulfur dioxide (SO2) may be occurring. The extremely large amount of traffic congestion likely produces elevated levels of carbon monoxide and toxic pollutants (such as benzene) associated with vehicle exhaust, at least in the immediate vicinity of busy traffic corridors. Monitoring for ozone is very limited, but at least some readings near the level of the U.S. standard have been reported.

B. Emissions Inventory

1. *Mobile Sources* Estimates of vehicular emissions for Metro Manila were prepared for 1990 by DENR and in 1992 as part of an ADB assessment. As part of the team's effort, data on fuel consumption was gathered and used to create an estimate of emissions for 1997. Estimates for PM10, VOCs, CO, SO2, and oxides of nitrogen (NOx) were made. The inventory is based, for the most part, on emission factors derived from information developed for vehicles in California. This was necessary because emission factors for the vehicles in-use in Metro Manila are not available. The results of this inventory are shown below.

Table 1. Estimate of Vehicle Emissions in Manila in 1997 in Tons per Year

Category:	*Pollutant:*				
	PM10	SO2	CO	VOCs	NOx
Gasoline Autos	350	2,400	270,000	60,000	18,000
Diesels Vehicles	12,000	18,000	33,000	9,100	60,000
Motorcycles	1,000	60	13,000	9,500	20
Totals*	13,500	20,500	316,000	79,000	78,000

*Figures for Totals are rounded to the nearest 500.

About 40% of the estimated 60,000 tpy of VOCs from gasoline autos is from evaporative emissions. All of the remaining emissions are from vehicle exhaust. The emissions estimates for diesel and motorcycle PM10 are based on emission rates developed for the 1992 ADB study. These are higher than the rates used for older vehicles in the U.S. and are probably more accurate of conditions in Manila. The other estimates for vehicles and motorcycles are based on information on older, non-catalyst cars, older diesel vehicles, and off-road, two-stroke motorcycles in the U.S. It was assumed that all of the low-octane, regular gasoline marketed in Metro Manila was used in two-stroke motorcycles.

While these estimates differ somewhat from the inventories done by DENR and for the ADB study, they lead to the same basic conclusion—that diesels are the overwhelming mobile source of fine combustion particles, SO2 and NOx. These are the pollutants that are most important in the formation of PM10, especially that portion that comprise the smallest fraction, PM2.5 and below. However, the diesel and motorcycle fleets in Manila contain many vehicles with excessive visible emissions, indicating that much higher emission rates are likely (for those vehicles) than the emission factors used here. If further work is done to refine the inventory, this issue should be addressed.

2. *Stationary Sources* Little new work was done as part of this effort to develop information on emissions from stationary sources. Existing information from EMB was reviewed, and data on fuel oil use were collected. An emissions estimate for SO2 was prepared using fuel supply data based on the assumption that the average sulfur content of fuel oil was 2.5%. This method produced a significantly higher estimate of SO2 emissions from stationary sources than reported by DENR for 1990 (260,000 tpy vs. 78,000 tpy). The conclusion that stationary sources produce a large majority of Metro Manila's SO2 appears true in any case, but this difference in estimates should be examined as air quality plans are formulated.

C. Design of a Regulation to Phase Out Lead in Gasoline

A sample rule was drafted and provided to the EMB on December 18, 1997. Removing lead from gasoline is necessary to enable the introduction of catalyst-equipped vehicles, and is also needed to reduce exposures to ambient lead. Once lead additives are no longer used at the refinery level, the phase out should occur rapidly as leaded fuel is displaced with unleaded throughout the fuel delivery system.

Based on CARB's experience on lead phase out in California, and knowledge of its impacts in the U.S. and other countries, the team does not believe that there will be any significant adverse impacts on existing in-use engines due to the switch to unleaded fuel. On the other hand, the adverse effects of lead on health are well-established and severe. Furthermore, the use of unleaded gasoline is essential to maintaining the efficiency of vehicle catalyst systems, now scheduled to be required in the Philippines by the year 2000. For these reasons, it is important that the lead phase out proceed as required in Executive Order 446.

D. Identification of Other Strategies to Reduce Air Pollution from Fuel Combustion

As indicated above, fuel combustion is a major cause of Metro Manila's severe PM10 problems, and is the major contributor of other pollutants. Relative to the U.S., fuel quality in the Philippines is poor in terms of emissions-producing potential. Improvements in fuel quality would produce substantial emissions reductions and air quality improvements.

The team evaluated a wide range of fuel specifications for their potential to improve fuel quality and reduce emissions in Metro Manila. This assessment examined the contribution of vehicles to emissions, the cost and technology needed to effect fuel changes, and the magnitude of the benefits likely to accrue. The team also reviewed fuel changes made in the U.S. to address similar pollution problems and evaluated how the types of fuel specifications now applied in the U.S. might improve air quality in Metro Manila.

E. Mechanisms to Fund Air Pollution Control Programs

Ideally, air pollution fees should be based on the actual emissions from sources that contribute to the problem, with the level of fees adjusted to reflect the magnitude of the workload created by the source on permitting and enforcement agencies, and the source's relative contribution to the overall air pollution problem. Under such a system, a source with great quantities of emissions or with emissions that pose a substantial toxic risk would pay high fees commensurate with its emissions. This would relate fees to the problems produced by the sources, and would also provide some financial incentive to sources to reduce emissions below the levels required by regulation.

However, it is unlikely that currently available emissions information is of sufficient quality or is comprehensive enough to implement a pure emissions fee system. Furthermore, it is unlikely that a fee system that produces sufficient revenues to fund needed activities would be set high enough to make it more economical to control emissions than to pay the fees. In light of this situation, a simpler approach to establishing fees could suffice. An example of how this system might work to create revenues of $5,000,000 (U.S.) is provided in the Recommendations section.

RECOMMENDATIONS

A. Design of a Regulation to Phase Out Lead in Gasoline

1. *Sample Rule to Phase Out Lead in Gasoline* A sample rule was drafted and provided to the EMB in December 1997. Once lead additives are no longer used at the refinery level, the phase out should occur in a reasonable time as leaded fuel is displaced throughout the fuel delivery system.

2. *Impact of Phase Out on Lead Levels* Monitoring data on lead from the 1992 ADB report indicate that lead levels between August 1991 and February 1992 averaged about 2.0 ug/m3 at the ADB monitoring site and comprised, on average, between 1.0 and 1.5% of the PM10. Using this ratio as a guide, and assuming that recent PM10 monitoring can be used to characterize conditions in the early 1990s, it appears that the regionwide annual average lead levels were in the order of 2 to 3 ug/m3. (Concentrations during the peak quarter and at stations most impacted by auto emissions would be expected to be much higher.) The introduction of low-lead gasoline should have reduced these levels by about two-thirds, to between 0.7 to 1 ug/m3. The complete phase out of lead in fuel should reduce these levels to near zero, except in areas where metal-working operations result in substantial lead emissions.

3. *Adverse Impacts on Engines* Based on CARB's experience on lead phase out in California and knowledge of its impacts in the U.S. and other countries, the team does not believe that there will be any significant adverse impacts on existing in-use engines due to the phase out of the use of leaded fuel. On the other hand, the adverse health effects of lead are well established and severe, and the use of unleaded gasoline is essential to maintaining the efficiency of vehicle catalyst systems, now scheduled to be required in the Philippines by the year 2000.

B. Identification of Other Strategies to Reduce Air Pollution from Fuel Combustion

Potential changes in gasoline, diesel, and fuel oil specifications to improve air quality were evaluated, taking into account Metro Manila's air quality problem, the contribution of vehicles to emissions, and the cost and technology needed to effect fuel changes. This assessment drew upon experience gained in the U.S. to modify fuels to address similar pollution problems. The rationale and potential benefits of changes to several fuel specifications to improve air quality in the near to mid-term time frame (next 1 to 5 years) are presented below:

1. *Potential Impact of Gasoline Specifications on Emissions*

a. Lower the allowable Reid Vapor Pressure (RVP) of gasoline from its current limit of about 12 psi (85 kPa at 37.8 degrees C) to 8.0 psi (55 kPa). RVP is a measure of the potential of gasoline to evaporate. The current maximum specification for the Philippines for RVP is quite high, considering the warm climate. Although representatives of oil companies indicated that in-use fuels were substantially below the required limit, they did not provide data on the current RVP of fuels. In warm climates fuels with much lower RVP produce much lower evaporative emissions, meet customer expectations for performance, and provide improved fuel economy (as less of the energy value of the fuel is lost due to evaporation).

California set a 9.0 PSI RVP (62 kPa) for warm weather fuel in the 1970s and dropped that limit to 7.8 psi in 1992. In warmer areas of the U.S., summertime RVP is now set at 7.0 psi (in California) or at 7.2 psi where federal "reformulated gasoline" is required.

Assuming current in-use gasoline RVP in Metro Manila now averages 10 psi, setting a new RVP limit at 8 psi would lower evaporative emissions of hydrocarbons and toxic compounds by about 5,000 tons per year (tpy) and exhaust emissions by about 1,000 tons per year (tpy). A change in RVP from 10 psi to 8 psi is relatively inexpensive (an estimated 1 to 2 cents per gallon) and would provide substantial VOCs emission reductions, in the order of 20% less evaporative emissions. Lowering RVP by this amount would also result in a reduction in exhaust VOCs emissions by approximately 2% for non-catalyst vehicles and several times as much for catalyst-equipped cars. Overall this would reduce mobile source emissions of VOCs by almost 10%.

RVP changes can usually be made at refineries without extensive capital investments, and can be implemented in a relatively short time frame (9 to 18 months) after they are established. Because fuel economy is enhanced, changes in RVP changes have only a small impact on fuel costs.

b. Reduce the sulfur level in gasoline. Lower sulfur will reduce SO2 exhaust emissions and will enable catalyst-equipped vehicles to maintain lower emission levels of pollutants. California now limits the sulfur content of gasoline to 40 ppm, and average in-use levels are considerably lower, as many refiners have chosen to limit sulfur to very low levels to gain greater flexibility for other fuel parameters.

While very low levels of sulfur are desirable in terms of emissions reductions, it is also possible to obtain substantial benefits at moderate levels of sulfur, in the area of 300 ppm, for much less cost. (In the U.S., costs are estimated to be 2 to 4 cents per gallon.) For catalyst-equipped vehicles, emissions reductions of 20, 40, and 25% for VOCs, CO, and NOx, respectively, would be expected as sulfur is decreased from 2,000 ppm to 300 ppm. SO2 emissions from gasoline vehicles would also be decreased by 85% from all vehicles.

Desulfurization facilities are capital intensive and require several years of lead time to construct. Therefore any changes in sulfur content that cannot be accomplished within existing refinery capabilities would likely require three or more years of lead time.

c. Require all gasoline to contain minimum levels of detergent additives. The use of such additives prevents plugging of fuel injectors. Plugging significantly increases emissions, and results in lost fuel economy and poor vehicle performance. Since 1992, California has required all gasoline to contain adequate levels of detergents to control this problem, and a similar requirement was subsequently enacted for the entire U.S. Small amounts of additives are used, and there are no refinery changes needed. Costs are small, less than one-half of a cent per gallon. Furthermore, the use of detergents provides other benefits to the consumer that help offset the increase in cost.

d. Cap the benzene level and aromatic hydrocarbon content in premium gasoline (octane level 87 and above) at 2% and 40%, respectively; establish tighter caps at 1% and 30% for regular fuel (if sub-87 octane fuel designed for motorcycles and other small engines continues to be allowed).

Benzene is a known human carcinogen that produces a substantial amount of the health risk associated with breathing gasoline vapors and exhaust. Much of the benzene in ambient air is the result of gasoline evaporation or the emission of benzene as part of auto exhaust. Benzene also results from the partial combustion of other aromatic hydrocarbons, and these compounds result in other emissions of concern. Reducing benzene in gasoline achieves a proportional reduction in evaporative and exhaust emissions. Reducing aromatic hydrocarbon levels further reduces benzene, and results in lesser quantities of other aromatics, as well as exhaust emissions of NOx, VOCs, and CO.

Benzene limits are currently set at 1.0% throughout California and in many other urban areas in the U.S. Prior to setting these limits, average benzene levels in California's gasoline were between 1.5 and 2.0%. Aromatic hydrocarbon limits are set at 25% in California. These regulations have produced somewhat greater than a 50% reduction in benzene emissions, because actual levels in fuels average well below the 1% limit. The major issue with reducing benzene and other aromatic compounds, other than cost, is replacing the octane boost provided by these compounds.

The current benzene specification for gasoline in the Philippines is 5%, and aromatic hydrocarbons are limited to 55%. Refiners indicate that the average level of benzene in gasoline is between 3 and 4%, and that aromatic hydrocarbons can amount to 50%. Refiners indicated that the use of benzene and other aromatic hydrocarbons is essential in their current facilities to maintain octane at desired levels.

In California, the average level of benzene in gasoline prior to regulation was about 1.7%, and aromatic hydrocarbons were about 32%. Setting levels for these components in the Philippines at California limits (1.0% and 25% respectively) would require far greater fuel than was required for California's reformulated gasoline. Attaining such low levels from existing facilities could also pose major challenges in maintaining octane levels. Also, as indicated by emissions and air quality information, diesel PM emissions reductions and sulfur control are probably a higher priority in terms of achieving the maximum health benefits from available resources.

Consideration should be given to establishing specifications for benzene and aromatics, but at more moderate levels than those in effect in the U.S. For example, limiting benzene to 2% for gasoline would still provide a 50% reduction in emissions from current levels and could be accomplished with far less extensive fuel reformulation and refinery modifications. Similarly, capping aromatics at an intermediate level of 40% would yield substantial benefits, but could be done at a lower cost (an estimated 2 to 4 cents per gallon) than implementation of the lower levels in reformulated fuels in California and the U.S. would require.

In addition, more effective limits on benzene and aromatic hydrocarbons in low octane, regular fuel may be appropriate. According to the area's refiners, this fuel is largely used in two-stroke engines, which emit about 30% of the fuel consumed as unburned gasoline. Having more stringent standards for this fuel would produce large emission reductions at a relatively low cost per ton of pollution reduced. Since these fuels have much lower octane levels, it is likely that lower benzene and lower aromatic hydrocarbon formulations would be feasible at a reasonable cost.

2. *Potential Impact of Diesel Fuel Specifications on Emissions*

a. Limit the sulfur content to 500 ppm by weight. The sulfur in diesel fuel is a significant contributor of emissions of sulfur oxides. These oxides consist of about 90% sulfur dioxide (SO2) and up to 10% particulate sulfates (SO4). The SO2 is converted to particle sulfate in the atmosphere, further worsening PM10 problems. Under favorable conditions, this conversion can involve a majority of the SO2.

The evaluation of the effects of reducing the sulfur content of fuels is straightforward. Each pound of sulfur in the fuel is converted to two pounds of SO2, except for the amount that is immediately transformed into particulate sulfate. Thus for each pound of sulfur removed, about 1.9 pounds of SO2 and 0.2 pounds of sulfates are reduced. During periods where there is a high conversion of SO2 to sulfate in the atmosphere, removing a pound of sulfur from fuel will remove about 2 pounds of PM10.

The current sulfur specification for the Philippines is 5,000 ppm, but is scheduled to drop to 3,000 ppm in the year 2000. Reducing sulfur levels in diesel to 500 ppm would provide very substantial air quality benefits at a likely cost of between 1 to 3 cents per gallon. A 500 ppm limit would reduce emissions of SO2 and sulfur-based particles by 90%, and reduce diesel particulates by 10 to 15%.

b. Limit the aromatic hydrocarbon content of diesel fuel to 25% and require a minimum cetane number of 50. California limits the aromatic hydrocarbon content of diesel fuel to 10%, but allows alternative formulations that achieve the same degree of emissions control. These specifications reduce PM emissions from diesel engines by an estimated 25% and reduce NOx by 7%.

Many current formulations in California use equivalent formulas (formulas shown to reduce PM and NOx to the same degree as a 10% aromatic hydrocarbon diesel fuel) to allow fuel to be produced more economically. These fuels typically have increased the cetane rating and decreased sulfur levels to achieve the emissions reductions obtained by diesel fuel that meets a 10% aromatic hydrocarbon limit. Allowing up to 25% aromatic hydrocarbons and requiring a minimum cetane number of

50 would provide a substantial portion (50 to 75%) of the benefits of the California program. This would amount to a 1,500 to 2,000 tons per year (tpy) reduction in diesel PM and a 2,000 to 3,000 tons per year (tpy) reduction in NOx in Metro Manila. If done in conjunction with refinery changes needed to lower sulfur levels, the increase in cost for fuel to meet these specifications should be in the range of 4 to 6 cents per gallon.

3. *Potential Impact of Stationary Fuel Oil Specifications on Emissions*

Limiting the sulfur content of fuel oil burned in stationary sources in Metro Manila to 0.5% sulfur by weight would create very large reductions in SOx emissions. Based on the inventory prepared by EMB for 1990, fuel oil combustion produces the majority of the SO2 emissions in Metro Manila, and is a significant source of the PM10 that occurs as sulfate particles. Existing fuel oil must only meet a 3% sulfur limit. Setting a cap on sulfur at 0.5% would reduce SO2 emissions by over three-fourths from stationary fuel combustion sources, and would also reduce PM10. A change in sulfur content could be accomplished fairly quickly if low sulfur crude stocks can be substituted for existing supplies. If desulfurization facilities must be constructed, a longer lead time, 3 to 4 years, would be needed. Costs for 0.5% sulfur fuel are estimated to be between 1 and 2 cents per gallon more than current high sulfur fuel oil.

4. *Changes in Type of Fuel and Engines*

Although they provide very substantial air quality benefits, fuel specifications alone are unlikely to provide the degree of reductions needed to approach health protective levels of air quality Metro Manila. Therefore, in addition to identifying specific fuel specifications that would reduce emissions from the current fleet, options that could produce even greater impacts in the mid- to long-term time frame (5 to 15 years) should be considered. Several of these are briefly discussed below.

a. Aggressively develop sources of domestic natural gas, and target large industrial and electricity production sources in Metro Manila for use of this fuel as soon as it becomes available. Even with only modest pollution controls in place, natural gas has much lower PM and SO2 than fuel oil, and emissions of these pollutants could be reduced to very low levels through such a strategy.

b. At time of rebuild, replace diesel engines with gasoline engines in the light- and medium-duty vehicles used for passenger transport in Metro Manila (jeepneys and utility vehicles). The rapid growth and "dieselization" of these vehicles in Metro Manila have produced extremely high concentrations of diesel particles. Gasoline vehicles inherently have much lower PM emissions and will create much less of a problem than that produced from the existing diesel-powered fleet.

c. Concurrent with the development of sources of domestic natural gas, introduce natural gas-fueled engines for the urban bus fleet and for other heavy-duty fleet vehicles with concentrated use in the metro area. Although the purchase price for natural gas-fueled engines is higher than diesel engines, fuel and maintenance costs are lower. Refueling stations are expensive, but are not prohibitive in high-volume locations. Overall lifetime costs of natural gas-fueled vehicles should be competitive with new diesel-powered vehicles. Such a strategy would achieve substantial PM reductions and would reduce NOx emissions.

d. Phase out the sale of new diesel vehicles in the light- and medium-duty categories unless such vehicles meet PM standards set for gasoline vehicles. Gasoline vehicles can perform all of the functions as diesel vehicles, yet produce far less pollutants of major concern.

C. Design of an Emission-Based Fee System

At present, the resources available to DENR for administering air pollution control efforts are quite modest, and implementation of a comprehensive program would likely be unsuccessful unless significant increases in funding for the agency are provided. Because of this situation, DENR requested ideas on how additional funding could be obtained. Some ideas are presented below.

Ideally, air pollution fees should be based on the actual emissions from sources that contribute to the problem, with the level of fees adjusted to reflect the magnitude of the workload created by each source on permitting and enforcement agencies, and the source's relative contribution to the overall pollution problem. Under such a system a source with great quantities of emissions or with emissions that pose a substantial toxic risk would pay fees commensurate with the environmental impact of its emissions. This would equitably assess fees and would also provide at least a modest financial incentive to polluting sources to reduce emissions below the levels required by regulation.

However, it is does not appear that available emissions information is of sufficient quality or is comprehensive enough to implement a pure emissions fee system. Furthermore, it is unlikely that a fee system that produces sufficient revenues to fund required activities would be high enough to make it more economical to control emissions than to pay the fees. In light of this situation, a simple approach to establishing fees appears necessary. The following elements are offered for consideration in such a system. An example of how such a system might be used to create annual revenues of $5,000,000 (U.S.), based on current fuel use and vehicle registrations, is provided.

1. *Fees from Stationary Sources*

   a. A permit fee that covers the direct cost of permitting the source and enforcing regulations via source inspections. These fees should be based on the direct and indirect costs incurred (by DENR or local agencies) because of the source. (For example, if annual permit renewal, annual inspection, and other related activities required 40 person hours per year, and the average cost of this staff time, including overhead, was $50 per hour, the source's annual permit fee would be $2,000.)

   b. A fuel use fee that produces the revenues from the industrial category needed to fund that category's fair share of the overall cost of administering air pollution control efforts. For example, if the industrial sector contributed 40 percent of the overall emissions in Metro Manila, collectively the fees from these sources would provide one-third of the revenues needed. Assuming $5,000,000 in total revenues are needed, a total of $2,000,000 would be collected from stationary sources.

      The level of this fee could be based on the quantity of fuel used and the sulfur content of the fuel. These two factors are a reasonable approximation of the source's contribution to emissions, and should be obtainable from existing data. According to data supplied by the DOE, about 28 million barrels (1.1 billion gallons) of fuel oil were delivered to industrial customers in Metro Manila in 1997. To generate $2,000,000 in annual revenues from this amount, a fee of about $0.002 per gallon (two-tenths of a cent) would need to be levied.

      Assuming that the average sulfur content of fuel oil is currently close to the 3% maximum and that few sources have any after-treatment control, this fee amounts to an emission charge of slightly less that a penny a pound (or $2 per ton).

      Once significant numbers of sources either obtain lower sulfur fuel or utilize other controls, it would be appropriate to establish a mechanism to lower the fee for sources that have emission control systems (for example a sulfur recovery unit), and to raise fees for those that do not, so that the required revenues are maintained.

2. *Fees from Vehicular Sources*

Because vehicles produce the majority of Metro Manila's emissions and resulting air pollution, it is reasonable that a fee mechanism that requires vehicle operators to provide revenues in proportion to their contribution to the problem be established. As is the case for industrial sources, a complicated system to tie fees to each vehicle's actual emissions is probably not workable. However, two relatively simple and reasonably equitable mechanisms are available and ought to be considered.

The first option would be to set a small per-liter charge on vehicular fuel at points of production. This fee could be adjusted to reflect the relative emissions associated with the fuel. For example, combustion of a liter of diesel fuel produces more of the pollutants that contribute to PM10 and SO2 problems than a liter of gasoline. The fee on diesel would be higher to reflect this difference.

To give an example of the level of such a fee, it is assumed that vehicles produce roughly 60% of Metro Manila's air quality problem, and that $3,000,000 must be raised through such a fee. According to data supplied by the DOE, about 12 million barrels (480 million gallons) of diesel fuel and about 8 million barrels (320 million gallons) of gasoline were delivered to customers in Metro Manila in 1997. To generate $3,000,000 in annual revenues from this amount, a fee of $0.004 per gallon (four-tenths of a cent) would need to be levied if both fuels were treated equally.

An alternative approach would be to establish per-vehicle fees to be paid at the time of registration. These fees could be adjusted to reflect the emission characteristics of the vehicles (for example, catalyst-equipped vehicles would pay lower fees). Roughly 1,000,000 vehicles are registered in Metro Manila, and the average fee would need to be about $3.00 per year per vehicle to raise $3,000,000 in revenues.

3. *In addition to the above, charges to vehicle manufacturers could be used to cover the resources devoted to certifying new vehicles and to enforcing the standards for these vehicles*. In California, these charges are now set at about $2.00 per vehicle sold.

D. Other Pollution Reduction Measures:

1. *Air Quality Monitoring* Expand the monitoring network to include a number of fixed sites that collect routine data on CO, SO2, ozone, and PM10. While sufficient information is available for Metro Manila to establish that there is a

very serious PM10 problem, monitoring for other pollutants is incomplete. Although the limited monitoring available has not defined a clear problem, the heavy concentration of sources of CO, SO2, and toxic organic gases suggest that high levels of these pollutants are very possible.

In addition, establish a program to measure high concentrations of CO, SO2, PM10, and toxic organic gases in areas affected by heavy traffic congestion. This could be accomplished by using a "rover" station that could be moved from site to site to collect short-term (several days to several weeks) monitoring data demonstrating the magnitude of exposures at suspected high sites.

Finally, analyzing the content of the filters could determine much information about the nature of the PM10 problem. The contributions of secondary particles such as nitrates and sulfates could be determined, and the contribution of direct combustion particulates versus soil-based fugitive dust could be better estimated.

2. S*moking Vehicles*. Many smoking diesel vehicles are in operation in Metro Manila. The visible emissions from these vehicles are accompanied by a many fold increase in particulate emissions during the episodes of smoke. In most instances, smoke can be greatly reduced through engine adjustments and other routine maintenance. In most cases, the smoke is so severe that a visual inspection is adequate to identify problem vehicles.

   A significant part of the diesel particle problem comes from these smoking vehicles and can be corrected in the near term through an aggressive effort to remove these vehicles from operation until proper maintenance is performed.

3. *Two-Stroke Motorcycles* Vehicle registration and fuel use information suggest that small, largely two-stroke, motorcycles account for about 10% of the vehicle registrations and consume approximately 1% of the vehicular fuel (based on sales of regular gasoline) used in Metro Manila. Although they consume a relatively small fraction of the fuel, these two-stroke powered vehicles contribute a disproportionately large percentage of the toxic organic compounds (13%) in the area. This is due to the fact that these engines have extremely inefficient combustion characteristics. Approximately 30% of the fuel used is not burned and is emitted as raw gasoline into the atmosphere. Another third of the fuel is only partially combusted and is emitted as CO. Significant PM10 emissions result from the emission of large amounts of unburned motor oil, which is added to the gasoline to provide lubrication for the cylinder. PM10 emissions from these vehicles are in the order of 1,000 tons per year, roughly 8% of the vehicle inventory.

Because of these high emissions, special consideration of measures to address motorcycles is warranted. One option (presented above) is to apply more stringent fuel specifications for benzene and aromatics in low octane fuel (sold as "regular" and often used in these vehicles) if this fuel continues to be allowed. Because this gasoline has very low octane, it can be manufactured with lower aromatic and benzene levels.

In addition to fuel controls, a program to remove motorcycles with excessive smoke should also be considered. Visible emission are a clear sign of very high PM emissions and oil use. Forcing the repair of these vehicles would produce a valuable contribution to reducing PM10 emissions.

Finally, equivalent motorcycle models that employ far more efficient (from a pollution standpoint) four-stroke engines are readily available and could meet the same transportation needs. On a per-kilometer-traveled basis, moderately controlled four-stroke motorcycles have about six times less organic gas and eight times less PM10 emissions than their two-stroke counterparts. Newly registered motorcycles in Metro Manila could be required to have four-stoke engines, and the operation of the high-polluting two-stoke motorcycles could be restricted over time.